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# Multiband photometric calibration and classification of galaxies in S-PLUS

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**Abstract.** Multiband photometry measures the energy output of an astronomical object in different wavebands. Using the 12 bands of the Southern Photometric Local Universe Survey (S-PLUS) we can employ the multiband fitting to extract physical parameters of the galaxies from its internal Data Release 4 (iDR4). We implement the fitting code Alstar to estimate galaxies parameters such as age, mass and star formation history. It was possible to perform multiband photometric fitting for 38,279 galaxies in iDR4. As this is a work in progress, we are in the process of developing a catalog with the results of the fitting for all galaxies in the main sample.

**Resumo.** A fotometria multi-banda faz a medida da luz proveniente de um objeto astronômico em diferentes bandas. Usando as 12 bandas do projeto Southern Photometric Local Universe Survey (S-PLUS) podemos fazer uso da técnica de ajuste multibanda para extrair parâmetros físicos das galáxias do quatro Data Release interno (iDR4). Com o código de ajuste da distribuição de energia espectral AlStar é possível estimar parâmetros tais como idade, massa e história da formação estelar. Foi possível realizar o ajuste fotométrico multibanda para 38.279 galáxias no iDR4. Como este é um trabalho em andamento, estamos desenvolvendo um catálogo com os resultados do ajuste para todas as galáxias da amostra principal.

**Keywords.** Galaxies: general – Techniques: miscellaneous – Methods: data analysis – Surveys

## 1. Introduction

This project aims to study all galaxies from the fourth internal Data Release (iDR4) of the Southern Photometric Local Universe Survey project (S-PLUS, Mendes et al. 2019) that have an estimated photometric redshift. This approach aims to use the large data volume from S-PLUS made up of precise measurements for more than 50 million objects, with a system of 12 bands distributed along the optical spectrum.

Multiband photometry measures the energy output of an astronomical object in different wavebands. Fitting the multiband photometry has some advantages over spectral fitting: more than one galaxy at a time can be observed and larger areas can be explored. Using the 12 bands of S-PLUS we can employ the multiband fitting to extract physical parameters of iDR4 galaxies.

We implement the fitting code Alstar to estimate the parameters related to the physical properties of the galaxies, such as age, mass and star formation history. With these properties in hand, we can build star formation history diagrams and study the evolution of these objects. Our ultimate goal is to create a catalog with these results. As S-PLUS is covering most of the southern hemisphere sky, it will be a study of great importance for the astronomical community interested in the extragalactic area.

## 2. S-PLUS

The Southern Photometric Local Universe Survey's main survey is imaging ~8000 $deg^2$ of the celestial sphere using the Javalambre 12-band magnitude system (see Fig. 1). The system includes the u, g, r, i, and z broad-band filters, similar to those from SDSS, and is also composed of seven narrow-band filters (J0378, J0395, J0410, J0430, J0515, J0660, J0861) that coincide with prominent stellar spectral features. S-PLUS also delivers accurate photometric redshifts for galaxies with r < 19.7 AB magnitudes. With a single epoch observation of each field, per filter, under photometric conditions, S-PLUS is ideally suited for studying galaxies in the southern hemisphere sky.

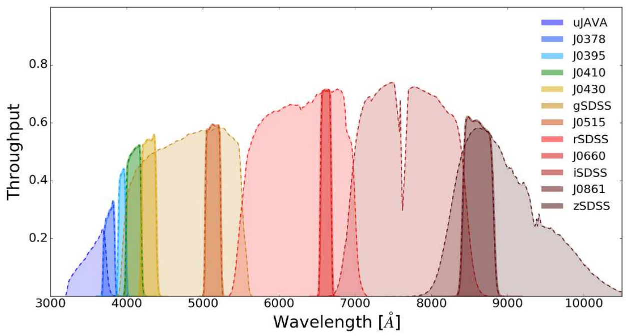


**Figure 1.** The Javalambre 12-filter system. Different filters are coloured according to the labels shown in the legend at the right.

## 3. AlStar

The idea behind spectral synthesis codes like AlStar is that a galaxy contains several stellar populations, so its observed spectrum is the sum of all these components. A model is then set up for this sum and an attempt is made to adjust the parameters of this model, so that the observed data can be reproduced.

In this context, AlStar is a code that performs an algebraic decomposition of an observed spectrum in terms of components that represent stellar populations of different ages and metallicities. This code is similar to Starlight (Cid Fernandes et al. 2005), with some significant differences, including the addition of emission lines to the spectral fitting. This is possible because, in addition to a spectral base of stellar populations, a base of nebular components is also included, whose spectra contain only emission lines. Another difference is that AlStar shifts both the stellar

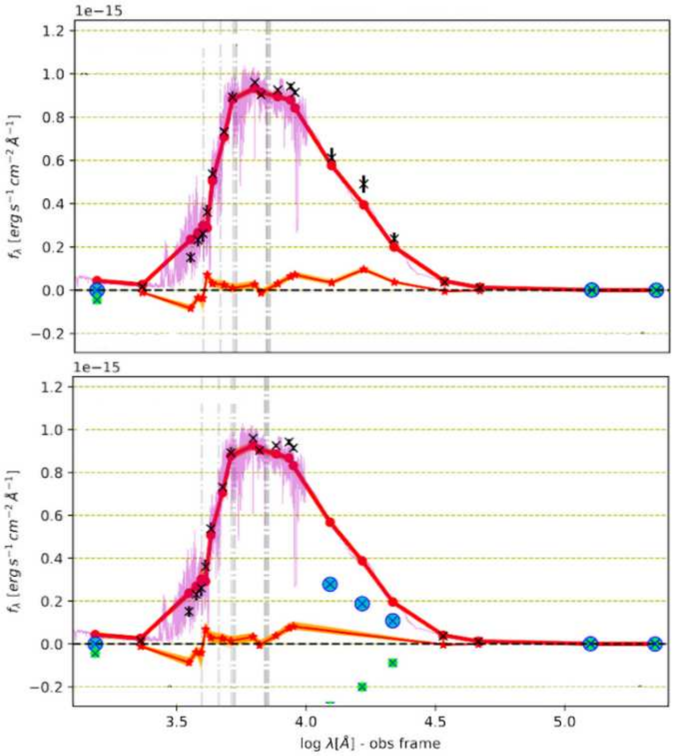


**Figure 2.** Spectral fitting for a galazy in the STRIPE82 region, with data from GALEX, S-PLUS, 2MASS and WISE. The fitting is shown in red (dots), and the respective residuals (stars). The blue circles refer to data that were not considered for adjustment. The thin lines, in yellow, show the perturbations calculated by AlStar, and in purple we have the model spectrum. In this particular galaxy, the FUV filter was not used. The top panel shows the fitting with 2MASS data and the lower panel shows the fitting without.

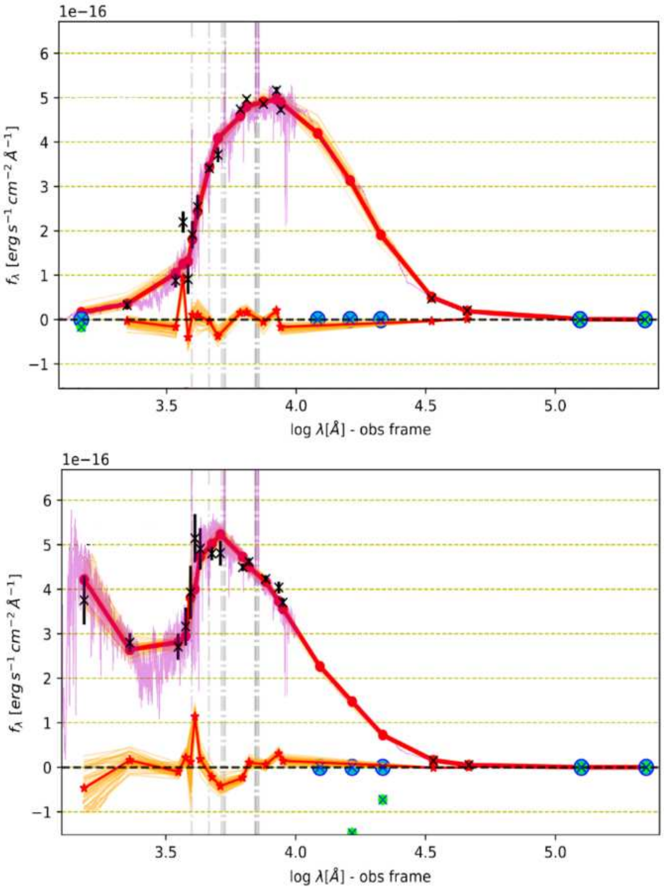


**Figure 3.** The multiband photometry fitting for two galaxies in the Hydra region, using GALEX (FUV & NUV), S-PLUS and WISE (W1 & W2). Upper pannel shows the fitting for a galaxy with low flux in the blue region of the spectrum. For this fitting in particular, GALEX's FUV filter was not used. Lower pannel shows the fitting for a galaxy with higher flux in the blue region, as expected the fractions of light and mass returned by AlStar reflect these stellar populations (see Fig. 4)

and nebular base spectra to the observed reference frame, taking into account the object's redshift. The code uses updated convoluted spectral models of Bruzual & Charlot (2003) for the S-PLUS filters and a chi-square minimization is applied to find the best combination of models that represent the data. From this combination, physical quantities are extracted, which can then be used to determine the evolutionary history of galaxies.

## 4. Data

In order to have a coherent sample, it is necessary to constrain the S-PLUS data. First, all objects must have an estimated photometric redshift (Lima et al. 2022) and the probability of the source being a galaxy is chosen to be greater than 0.9 (Nakazono et al. 2021). As this analysis seeks to study galaxies, objects with Petrosian magnitudes (Petrosian 1976) that are less than 18 in the r band are selected to constrain the magnitudes in the fainter end. For the main sample, a restriction regarding the relation between photometric (photo-z) and spectroscopic (spec-z) redshift was also imposed on the data, with the intent that 96% of the objects have a difference of less than 0.03 between the photo-z and the spec-z.

The result is cross-matched with other surveys, the Galaxy Evolution Explorer (GALEX, Martin et al. 2005) for data in the ultraviolet region (FUV and NUV filters) and the Wide-field Infrared Survey Explorer (WISE, Wright et al. 2010) for data in the infrared region (W1 and W2 filters). In a first analysis, we used data from the internal Data Release 3 of S-PLUS (iDR3) to explore the area of STRIPE-82 and create an initial sample for an in-depth study. It was necessary to use iDR3 because at the beginning of this project iDR4 had not yet been made available. In this initial sample, the photometric data from the S-PLUS was crossed with the GALEX, WISE and also with the Two Micron All Sky Survey (2MASS, Skrutskie et al. 2006). Figure 2 shows the fitting with and without the 3 bands from 2MASS. The data from 2MASS (J, H and K bands) did not contribute to an improvement in the fitting, as result this data was not used in the subsequent analysis.

## 5. Results

It was possible to find 38,639 objects in iDR4, filtered according to the criteria established in Section 4. Of those, AlStar returned 38,279 fittings. This lag occurs due to a characteristic of the code, in which only objects with a minimum number of valid magnitude inputs are considered.

Figure 3 shows the fitting from AlStar for two galaxies in the Hydra region and Figure 4 shows the cumulative mass and light fractions, for the same objects. Upper pannel shows a galaxy with older stellar population and the lower pannel shows a galaxy with younger stellar populations contributing to the

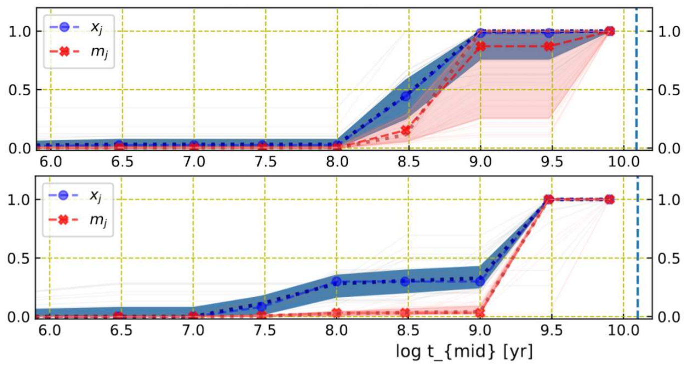


**Figure 4.** Cumulative mass and light fractions for two galaxies in the Hydra region (see Fig. 3 for the spectral fitting). In blue we have the light fractions and in red the mass fractions.

light fractions but older populations contributing to the mass. As expected for the galaxy with low flux in the blue region of the spectrum, we have most of the light and mass attributed to older populations. The opposite occurs for the other galaxy, in which younger populations contribute significantly to the light fraction, and the mass fraction is dominated by older stars.

A portion of the objects also returned a compromised result due to the presence of outliers in the S-PLUS photometry. With this, we identified the need for a flag system in out final catalog. With these results in hand, it is possible to extract the parameters related to the physical properties of these objects, such as age, mass and metallicity.

## 6. Conclusion

By fitting multiband photometry to S-PLUS iDR4 galaxies, physical parameters were extracted from 38279 objects. As this is a work in progress, we are in the process of developing a catalog with the results of the fitting for all galaxies in the iDR4 main sample. In addition, we intend to estimate the projected density of these objects and assign a probability that a galaxy belongs to a certain group/cluster. As a result, galaxies in the southern hemisphere can be studied in terms of their evolutionary environment.

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